Deploying a low-cost data service in rural areas using WiMax over GSM/GPRS

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In some South African rural areas, GSM networks have spare capacity. The available capacity is usually not fully utilized and other services can be developed to use capacity more effectively. One possibility is to try to use this spare capacity to provide a low speed data service to rural areas.

When we speak about data access through a public land mobile network (PLMN), general packet radio service (GPRS) comes to mind, but GPRS access is not well adapted to our problem. One of the reasons is that we do not need to cover an entire area. In many rural areas, requests to access a data network are extremely localized (town hall, administration center, hospital, backpacker hotel, internet café, etc. [1]). A point-to-point access to the PLMN is therefore more suitable than GPRS. Since subscribers needing data access in these areas are not only extremely localized, but can also be distances of up to fifty kilometers apart from each other, WiMax can be used to extend services and increase range. It is therefore interesting to investigate a way to access the PLMN over the GSM classical core network using WiMax technology.

In the first part of the paper ideas to build a WiMax network interfaced with a GSM network are introduced (refer to Fig. 1). This solution, introduced in section II, is certainly an option, but a 64 kbps link is permanently used. Since the provision of a permanent 64 kbps link is not a perfect solution, a best-effort service over a classical GPRS core network is introduced in the second part of the paper.

WiMax over GSM

This section is divided into two parts. First we discuss some ideas about interfacing WiMax with GSM and then the reasons for building a network based on WiMax point-to-point connections are presented. In section II.B the interface between WiMax and GSM is presented. This interface consists of a PC (configured as a router) connected to the digital cross connector (DXX) using a LAN module. Minimal modifications have to be made to the base station controller (BSC) and mobile switching centre (MSC). The PC is equipped with a Linux kernel modified and adapted to the new protocol in order to offer a classical network interface to the application layer. Classical quality of service or load sharing applications can therefore be used transparently.

Modifying GSM network

To interface the PC with the GSM network, several modifications were implemented. We interface with the DXX, therefore the base station transceiver (BTS) configuration does not need to be modified. Minimal changes have been made on the BSC and on the MSC. As shown in Fig. 2, a semi-permanent connection is established through the BSC and through the MSC. The idea is to establish a direct connection between our interface and the interworking unit (IWU) in the MSC. The IWU can be connected to the net through the PSTN or through ISDN. Its job is to convert data from PLMN to analogue data, for instance, if the IWU is connected to the net through the PSTN [2]. Finally, the WiMax interface is directly connected to the IWU by reserved time slots to establish a connection to the net. Instead of having to respect GSM protocols to communicate with BTS, the interface has just to communicate with the IWU.

Modifications to the Linux kernel

To communicate with the IWU, a new protocol was developed. Its function is to establish a connection to the IWU and to organise IP data in order to make it understandable to the IWU. As shown in Fig. 3, this protocol is localised between IP and Ethernet on the OSI layer scheme, where Ethernet is the data link protocol. Our interface is connected to the DXX using a single Ethernet card.

The implementation of this new protocol, called the IWU protocol, is divided into several parts. First, main functions of this protocol have to be implemented in the kernel domain. Then, in the user domain, a daemon called iwud is implemented in order to take care of signaling to establish or to terminate a connection. Finally, this protocol should be transparent to applications such as quality of service or load sharing software.

On a Linux system, the only way applications can communicate with the kernel is by using the system call socketcall. Although this system call is almost never used directly by programmers, libraries using this call were developed.

So, the point is not that applications reach the IWU protocol (because user applications only access a upper layer) but that the IWU is called by layer 3 (IP in this case). The classical way to do this is to use a structure called net_device.

The Linux kernel provides an interface to the middle of OSI layer 2 (see Fig. 4) and since programming under this layer depends on the hardware used, kernel developers have defined a software interface in order to allow designers to easily create kernel drivers. This interface is a C structure called net_device.
When a packet (the skb structure in Linux is associated with a packet and contains all packet data including headers and functions) is processed by the IP layer, the IP protocol calls skb->dev->dev_queue_xmit where dev is the net_device structure. This means that, if a new interface (called iwu) is set up, the IP protocol will call it (obviously if a routing table shows that this kind of packet must be forwarded to the iwu interface - more information can be found in [3]). At this layer, routing facilities of Linux and classical applications can be used. Although IWU is transparent, the iwu interface is not the final destination. The iwu interface is implemented as a tunnel interface, since it is not linked to specific hardware. After a packet has been processed by the IWU protocol it is forwarded using the classical dev_queue_xmit call of the Ethernet interface.

Creating a best effort service using GPRS core network

The GSM core network is circuit switched and so it cannot be easily used for the purpose of providing a best effort service to the WiMax sub-network. The GPRS core network is more suited since it is packet switched. The question of using the GPRS core network as a backbone, is therefore worth investigating.

By definition, best effort traffic should not have any influence on classical GPRS traffic. On the GPRS core network this implies that GPRS equipment supporting GPRS support node (SGSN), gateway GPRS support node (GGSN) and other network resources have to treat WiMax data as a second priority.

In section III.A, a way is described to create a best effort service within an SGSN. In section III.B it is explained how to configure the Gb interface on the SGSN and BSC to have best effort traffic in the network even if the GPRS operator uses a frame relay provider for the interface.

Using GPRS to create a quasi best-effort service within SGSN

A software solution (which is possible since some GPRS platforms use open source systems like Open Telecom Platform [4], [5]) allows

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**Fig. 2: Modifying the GSM network.**

**Fig. 3: Adding a new protocol.**

**Fig. 4: OSI layer and Linux kernel.**
for a real best effort treatment, but will require extensive testing before deployment. It is possible to have an easier less costly solution which provides a quasi best-effort treatment by using available QoS mechanisms. The GPRS standard provides different classes of service by defining some QoS attributes such as precedence class [6], delay class [7], reliability class [7], etc. SNDCP protocol [8] provides different classes of services to the upper layer.

**Best effort traffic on Gb interface**

Sometimes layer 2 of the Gb interface is provided by a frame relay operator. This is the reason why acting on the traffic has to be done just after SGSN or BSC. To do this very few modifications have to be made to the BSC and SGSN in the network service layer [9]. From the network service layer point of view, the connection between a BSC and SGSN is identified by a network service virtual connection identifier (NSVCI) which maps a frame relay permanent virtual connection (PVC). The idea is to multiplex two NSVC on the same PVC. Two classical routers are used as multiplexers. These multiplexers allow one NSVC to have priority over the second one, which becomes best effort from the network point of view (Fig. 5). Between the BSC and SGSN a new NSVC is defined. Data from our service is routed to this new NSVC. The previous sections, GPRS protocols have to be strictly adhered to for access provided by WiMAX equipment. As shown in Fig. 6, a WiMAX interface emulates a simple GPRS call to the BSC and to the GPRS core network. This interface simulates a mobile station requesting a GPRS call, creating a PDP context. A best effort access is provided on the PCM link between BTS and BSC by using empty time slots reserved for a BTS if some are available. If not, data are buffered on the interface.

**Conclusion**

In this article, we have demonstrated that WiMAX technology can be used to provide access to localised rural points of demand, using GSM/GPRS as a core network. Since the Abis interface is used, no significant operator costs are incurred. Very few modifications on the GPRS core network (done just by properly configuring the SGSN, GGSN and BSC) have to be made to implement a quasi best-effort service which has no influence on classical traffic. The only costly components of the proposed system are related to WiMAX deployment making the described solution extremely cost effective. WiMAX for rural access over GSM/GPRS could become a cost-effective solution for providing data and internet access to underserved rural areas in years to come.

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